

THE LIFE HISTORY, HABITS, AND
CONTROL OF THE ARIZONA FIVE-SPINED
EPS. *Dr. Lucius SWAINE*
(COLEOPTERA: SCOLYTIDAE)

By
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INTRODUCTION

The Sonoran Desertwood type, *Jun* *leucosticta* Barker, is one of the most important pests of ponderosa pine, *Pinus ponderosa* Lamb., in Arizona. Within this insect's range in the United States it is directly associated with almost all the losses in ponderosa pine caused by bark beetles. In 1937, the last year systematic aerial insect surveys were flown throughout Arizona, *J. leucosticta* was associated with approximately 400,000 acres of bark beetle-killed ponderosa pine (Frost and Harris 1938). By 1944, the severe losses of ponderosa pine made a study of the habits of *J. leucosticta* imperative.

Life history studies were begun on the Prescott National Forest in Arizona with the eventual aim of developing a control method. Most of the Prescott National Forest is in the "chirp" ponderosa pine type, largely second-growth, with pine stands predominating. Here the collection and breeding values obtained the stated values of the pines.

Until the present study little was known of the habits of *J. leucosticta*. It apparently had similar habits to the California five-spined engraver, *Jun* *griffiths* (Saw.) which is morphologically (Shanklin, 1939). Known in California *J. griffiths* is a pest of two species of pine, particularly ponderosa (Stebbia and Hill, 1934), it confined its attacks almost exclusively to pines, *Pinus* *edulis* Engelm., in Arizona and New Mexico. The ecological niche of *J. griffiths* in ponderosa pine is taken over by *J. leucosticta* in southern Arizona and by the pine engraver *Jun* *pin* Say, in northern Arizona and New Mexico.

SECTION OF LITERATURE

Endoparasites and Agrostids

Im. longicaud was originally described by James Clark Ross as a species in the Endoparas collection labelled longicaud. Description: "This species is of the same size and form as longicaud. It differs from the usually first and smaller intestinal parasites of the same genus, particularly by the length of the first decidental tooth which is distinct from the second, whereas between the first and second being each greater than the fourth, fifth and sixth, situated as usual on the last interspace, but with the last three straight and parallel with the others, not divergent behind as in longicaud."

"Endoparas 3, the distinct type of longicaud lies in the Johns collection, Agassiz Museum, Harvard University."

"Parasites - No. 37 No. 378 is the Canadian National Collection, Ottawa, Ont., Final No. , Arizona, Ind. Brewster, Arizona, No. and 40, 41, 42."

Schell (1941) placed Im. longicaud in synonymy with Im. longicaud. Ross (1941) stated that Im. longicaud was a valid species because of "the position of the first decidental tooth and characters of the male genitalia."

Although the position of the decidental tooth (Figure 1) has been used as a characteristic in separating Im. longicaud from Im. longicaud, the latter is perpendicular to the polar setae in both areas of

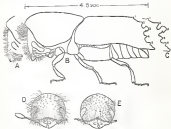


Figure 1. Larva of the sawfly. A: Head of male. B: Female. C: Dorsal view of male. D: Head of female (dorsal view). E: Head of male (dorsal view).

J. longicaud (Figure 4) are lacking in J. confinis and the two species may be separated on this feature alone.

Schott (1961) connected himself and agreed with Wood that J. longicaud was a valid species separate from J. confinis, but suggested that J. arcticus (Wood) although much smaller, might be a geographical race of J. longicaud.

In his revision of the genus Jug, Hopping (1960) placed J. longicaud in "Group IX" of North American Jug. Group IX includes the only five North American species having five spaces on each side of the suboral declivity. Jug confinis, J. grandis (Wood) 1, and J. arcticus (Wood) 3 differ from J. longicaud by the placement of the first and second declivital spaces. Jug arcticus is less than 4 mm in length while J. longicaud is 4 mm or longer. The males of J. longicaud have a bifid median tubercle on the apical margin, obsolete in the female, while both sexes of J. arcticus have a median tubercle separated from the apical margin by the width of an eye. In addition, J. arcticus lacks the fine stripes near the polar corners

Separating the Species

The sexes of J. longicaud can be readily distinguished by secondary sex characters. Hopping (1960) used the granulation of the head as the principle means of differentiation. Besides the bifid median tubercle, which the female lacks, this male has a large granule on either side of a glabrous area on the frons which is obsolete in the female. The apical margin of the male has several large granules flanking the median tubercle, while the female has a row of small granules on the apical margin. Also, the front of the female's head bears many more



Figure 3. Ventral view of head of 2nd instar larva, showing fine striae perpendicular to polar setae.

longer than that of the male's. The female has a row of granules on the declivital interspace which is obsolete in the male and the declivital spines of the female are smaller than those of the male.

Reed (1961) found a stimulating organ on the vertex of the head of the females of three western species of *Agis* including *A. apicalis*. Williams (1965) found the same organ on the head of the females of three northeastern *Agis*. The females of *A. [apicalis]* also have this organ, the *Agis viridula*, on their heads and this structure allows rapid waving of live beetles. A beetle that squirms when pulled by the fingers is a female. Identification can be made by separating the beetle until the head protrudes from the granules. Then the heavily colored head of *Agis viridula* can be seen with a 10X hand lens.

Host Trees and Distribution

Agis [apicalis] has been collected from five species of the genus *Fagus*. *Fagus grandifolia* is apparently the major host, although the host beetle fauna of Mexican and Central American plants have not been thoroughly studied. Schell (1964) lists *A. [apicalis]* with *A. [apicalis]* Schell as hosts in Guatemala. Shopp (1965) mentions collections from *A. [apicalis]* Barkbeetle in Mexico. Fennel (1966) reared *A. [apicalis]* from beetles of recently killed *A. [apicalis]* from the west slope of the Caribbean Mountains in Panama.

The most western and northern collections are from the Lower Sonora and Juarez, Arizona (Shopp, 1965). The most northern record is from *A. [apicalis]* in western Honduras (Williams, 1964). Shopp (1965) mentions records from Chaco, Rio Mucuna, the most easterly record of *A. [apicalis]* in the United States.

Bark Resistance

The action of bark attacking bark beetles on white bark trees has been long debated. Carson (1941) suggested that the silver firm fermenting inner bark of white bark trees attracted the first attacking Dendroctonus brevicornis (see white-). These beetles introduced galls which in turn spawned and attracted more beetles. Anderson (1943) felt that galls were attacked at random by D. pini. After a tree was successfully invaded the attacking beetles themselves became the stimulus for other beetles. Finally, the tree was overcome and killed. Since 1941, studies on bark resistance to bark beetles based on chemical excretion products (e.g. 1945) and the discovery of an attractive pheromone produced by males of D. confusus have shed new light on the method by which the bark trees of Jun spp. are selected and successfully attacked.

Yates (1941) measured the s.e.p. of ponderosa pines by inserting hydrostatic pressure gauges (Fournier type) into holes bored into the sapwood. He found that the pressure varied from 8 to 11 atmospheres² depending on the size, weather conditions, soil moisture, and physiological condition of the tree. Low soil moisture resulted in a low s.e.p. in the trees. Trees completely defoliated retained more bark beetle resistance as long as sufficient sapwood with the resin kept the s.e.p. above zero.

In a four-year field trial, Yates and Wood (1941) found that D. brevicornis and D. ponderosae Say³ (ponderosae Say)⁴ successfully

1. See atmosphere equals 14.7 pounds per square inch.

2. The unit in parentheses is a synonym used by the authors. (See Wood, 1943).

attained approximately 10000 gms (100 mg) of NaCl over 48 hr (1966) with an average pair per acre made less frequently killed. Wood (1965) observed that L. confusus was only able to overcome an a.s.p. host area in postharvest grain. He found that cut, ungrazed postharvest grain reached an a.s.p. of zero in less than 24 hours.

Observations on the correlation between drought and bark beetle epidemics have been published by Fischer (1958), Engelbrecht (1958), and reviewed by Bolander (1962). Bell (1961) found that outbreaks of L. confusus could be predicted by measuring phloem-sap flow from April to July. However, the a.s.p. studies of bark beetle host trees were the first physiological investigations of the basis of host susceptibility.

During an investigation of the host selection behavior of L. confusus Anderson (1964) and Wood and Vite (1964) found that the initially attacking males emitted a secondary attraction to other males and females. Vite and Gure (1965) determined that the chemical responsible for the mass attacks of postharvest grain by L. confusus, L. pallidicornis (Gure) (= gambianus for L. and L. horvathianus spp. species specific, efficient over long distances, and produced by the males of the L. species and the females of L. horvathianus.

In a laboratory test to attempt to localize the source of male attractant in L. confusus, Wood (1965) found that newly emerged males were not attractive, but became so after feeding in the phloem. He also found that the phloem alone that had been fed on by the male was attractive after the male was removed. Pritts and Vite (1964) found that the source of pheromone in the blood of certain male L. confusus and that the male's fecal pellets are highly charged with the pheromone. Later observations by Pritts et al. (1966) implicated the Malpighian tubules

as another source of pheromone production: Evis et al (1961, 1962) found that the pheromone is released only after the newly emerged males had fed for several hours on new host material. Thus, the "priming"-including males must feed and defecate in order to guide the attacking flight to suitable host material.

Flight Behavior

The flight of *J. pallidus* consists of a dispersal phase and a concentration phase (Evis and Evis, 1962). The dispersal phase allows the adult males to find suitable breeding material, while the concentration phase leads to successful colonization. The same authors found flights of *J. pallidus* to be dependent mainly on temperature and amount of attractants. In addition, they showed that several *J. pallidus* exhibited diurnal and seasonal flight patterns with most activity around 1:00 PM in the spring and 4:00 to 8:00 PM in the summer. *J. pallidus* initiated flight in the evening at air temperatures of 20 to 30C but tests showed that the insects' bodies absorbed enough solar heat to raise their body temperature 1 or more degrees above that of the air. Flight was stopped when air temperatures rose above 30C (Evis and Evis, 1962).

Evis and Evis (1961) collected *J. pallidus* from olfactometer traps over 500 meters from the release point. More beetles were collected in olfactometers placed upwind from the release point, although marked beetles were also collected from downwind olfactometers. Ross (1949) found that *J. pallidus* males responded best to attractants placed within 10 meters of the release point, females respond 50 percent better than males to attractants placed near the ground between 50 to 100 meters from the release point. Wilkinson (1964) demonstrated that *J. pallidus* and *J. grandis* were attracted to male-infested bolts placed to at least 50 feet above ground.

Wright et al. (1964) tested the flight pattern of large porcupine-log beetles flies in the morning and afternoon. Top graphically correlated flight to a one-hour period between 4:00 and 4:30 PM, while J. galligenoides showed a slight peak of flight activity in the morning and afternoon. Williams (1964) found a similar flight activity pattern for J. galligenoides in Florida.

The flight patterns were determined for several isolates tested by Ogden and Stephens (1967) using video traps.

Factors, Ecology, and Chemical Control

There have been comparatively few data published on the cultural and biological aspects of log control. Ross (1964) listed five factors generally influencing the building of bark beetle populations and applicable to log:

- 1) Availability of bark beetles
- 2) Vigor of the bark beetle species and strains
- 3) Natural control factors
- 4) Weather and environmental conditions
- 5) Abundance of food supply

Since log beetles characteristically build up high populations in slash and logging debris, Pirake and Hall (1966) suggest that logging operations, including thinning and land clearing, be done from July 15 through the winter. They also suggest utilizing logs to an 8-inch top diameter which would reduce surface areas for engraver broods by more than 50 percent. Logging and skidding the remaining slash to expose as much bark area as possible to solar radiation will further reduce the bark area available to log broods.

with *B. longicauda* (mean 1.1 versus 0.67) and *B. longicauda* (mean 0.57) and was pulled out of the *B. longicauda* group 4 × 10⁻⁴ as compared to 1 × 10⁻⁴ for *B. longicauda* (group 1). In addition, Henry (1961) found that the egg laying period of *B. longicauda* was reduced 45 percent when the larvae were defoliated by the nematode, *Steinernema glaberrimum*. Smith (1961) found up to 7,000 eggs and larvae of *B. longicauda* in one female *B. longicauda*, with a resultant loss of the cells and destruction of epidermal tissue of the host beetle.

Although biological control is important in reducing *B. longicauda* from under natural conditions, there are no records of *B. longicauda* controlled by biological control agents alone.

Wetrick and Stone (1964) tested eight chemicals and a mixture of them on slash pine prepared to prevent *B. longicauda* and nematode injury. They found lignans hexachloride to be the most effective. Stone (1967) tested four chemicals against *B. longicauda* and *B. longicauda*. Lignans proved to be the most toxic to *B. longicauda*, followed by malathion, DDT, and DDT-phos. Stone (1967) also found lindane to be toxic to *B. longicauda* and he prepared a set of directions for its use (Stone, 1967).

Henry (1961b) treated 748 green postlarval pupae in the Mexican with 2 × 10⁻⁴ percent solution of DDT at the end of May and the middle of July, and 1,000 were left untreated. In September, 194 untreated pupae were killed by *B. longicauda* (*B. longicauda* 100%) and only three of the treated (0.4%). Wetrick (1967) treated slash pine logs with 0.001 DDT and 0.001 DDT, 15%, two new chemicals. Seven DDT applied at concentrations of 0.1, 0.2, 0.4, and 0.8 percent protected the logs from nematode and nematode injury for approximately six weeks. Henry, at the same concentrations, for three weeks.

independently designed sprays that have proven efficacious.

Following back feeding and their removal beneath the bark of collected trees, Massey et al. (1960) found better evidence of ethylene chlorohydrin effective in killing *B. ponderosa* in standing trees. Kephart (1964) tested evidence of orthodichlorobenzene, ethylene chlorohydrin, DDT, and chloroform at the rate of 4-8 pounds of active ingredient per 4-5, 6, gallons of solution containing 90 percent fuel oil against adults and young larvae of *B. interpuncta* (Osaka). DDT and chloroform killed pupated adults, but mortality of the pupae was negligible for all treatments. However, he found evidence of ethylene chlorohydrin, diazinon, heptachlor, lindane, and dieldrin at 1-2 pounds active per 4-5, 6 gallons of solution effective against *B. ponderosa* & *intermedia* (both 1-2 adults and mid.) (1964) measured toxic penetrating oil applications consisting of 1 part orthodichlorobenzene to 4 parts "crude oil" or diesel fuel or 1-4 pounds ethylene chlorohydrin in 4 gallons oil, for killing *B. ponderosa*.

MATERIALS AND METHOD

The major part of these investigations was conducted in the greenhouse glass type in the Forested Wetland Forest, Foreman, Arizona, and in the Forest Insect Laboratory of the USDA, Rocky Mountain Forest and Range Experiment Station, United States Forest Service, El Segundo, San Mateo, from 1969 to 1971.

The study was conducted under three general headings:

- 1) Laboratory Studies
- 2) Field Studies
- 3) Chemical Control

Laboratory Studies

First colonies of J. lecontei were reared in the laboratory in order to determine the number of larval instars, the duration of each stage of development, and the feasibility of J. lecontei under controlled conditions. The larvae of J. sp. are difficult to separate from other weevils and field collections of J. lecontei larvae often include larvae of other species.

Life stages and galleries

For life stage studies and greenhouse glass bolts approximately 4 inches in diameter were used on both ends to measure moisture and placed in five-gallon metal cans, two bolts in a can. The cans were placed in a starting cabinet at 70° to prevent RLB. Fifty weevils, mostly J. lecontei, which were collected in the field and introduced to the bolts

larvae (mean ± 1 SEM) (mean ± 1 SEM) of 1000 eggs per petri dish. The before and the egg periods collected. The stage of development, sex ratio, and larvae were collected for head capsule measurements to determine the number of instars.

In addition, 50 larvae were reared individually in 20 ml vials which stopped with cotton. A slurry of fresh insect production plus bark was prepared by stopping 20 grams into small pieces, adding 20 grams of distilled water and 1 gram of sodium borate to inhibit mold. The mixture was placed in a Waring blender and broken into a paste. Excess water was permitted to evaporate rather than be absorbed out since the larvae did not survive in the evaporated-dried medium. When water did not drip from a hand-held sample, the medium was refrigerated until used. Individual eggs were placed in a vial filled with rearing medium which was changed every two days since it quickly dried. When fresh medium was added, the old medium was examined for natural head capsules. Washing the discarded phores with water aided in locating the capsules. Usually only the smallest remained, the rest of the natural head capsules were isolated when the larvae ate their medium.

Several attempts were made to observe gallery construction and boring behavior by enclosing 4-by 4-inch sections of insect bark between sheets of glass similar to the method used by Robert (1940) and Hogg (1941). Celluloid, used in place of glass, was unsatisfactory. Gallery construction and larval feeding could be observed for a short time until the boring dust produced by the beetles obscured observations. Celluloid facilitated rapid removal and cleaning of the dish, but the surfaces of the beetles covered the inner surface and made the celluloid opaque.

Experiment 2

The total number of eggs of naturally infested *agrotis* was determined by counting the egg masses along the galleries of *A. noctuidae* reared in the laboratory and from naturally produced galleries in the field.

A total of 34 galleries were examined from laboratory rearings. These galleries were examined by new adult females who were permitted to complete these galleries.

The field data were obtained by counting the number of eggs in each gallery in naturally infested trees and also the number of eggs laid by these new females when they re-occupied to make new galleries. The re-occupying parent females were trapped in wire screen cages (Figure 10) and placed in groups of 20, 3 males and 1 female, into 20 mesh cages, each containing an 18-inch ball of pine. To C. L. Murray found that *A. noctuidae* readily attempted to leave mesh cages containing pine bolls, and readily attacked the bolls. Feeding was maintained in the field by daily watering of the mesh.

At the end of 24 days when the galleries were completed, but before the new larvae could obliterate the gallery pattern with their feeding, the bolls were picked and the number of egg masses produced by the adult females was counted. Since the egg masses had been destroyed (eaten) when were counted, but this introduced an error: that of destroyed or undetected eggs.

The parent adult females were uncollected and the survivors, a total of 11, were placed in a mesh cage containing two 20-inch bolls to see if they would make a third attack.



Figure 3. *Lecanora vulgaris* on pole sized ponderosa pines infected with *Doth. lentispora*.

The egg-laying ability of mated females

In order to determine if new females habitually mated before beginning their dispersal flight, a series of tests were conducted involving three groups of I. leucostri adults: 1) males, 2) newly mated females that could not possibly have mated, and 3) emerging females collected in various cages as they emerged normally. In these tests, beetles in group 1 will be called "mated" and those in group 2, "unmated." The mated group were placed in small bins with phloem to completely harden for one week before being used. The unmated females were used as an operative control to the mated group in case of the possibility of parthenogenesis. A type of parthenogenesis has been found in other Iga spp., but never in species closely related to I. leucostri (Gardner and Oliver, 1944).

The host material used in each test was five 18-inch balls of fresh potter's clay. Two artificial nuptial chambers were cut into each ball and the balls were placed individually in wooden racks in the field at Fowcett, Arizona.

Test 1 - In the first test 18 pairs of unmated and 18 pairs of mated beetles were used. They were placed by hand into the artificial chambers.

Test 2 - The same number of unmated and mated beetles were used as were used in the first test, but in addition, 3 nuptial chambers contained a male, each with 3 unmated females. The beetles were confined to the nuptial chambers by 18 no shell vials held in place with modeling clay.

Test 3 - A repeat of Test 1.

Field Studies

Geographical Distribution

During the summer of 1958, a collecting trip was made through the ponderosa pine type of Arizona and New Mexico to delineate the range of J. lecontei in the United States. Collections were made of Jm over three old pines showing falling foliage. Collections made were gathered from the Forest Insect Laboratories at Berkeley, California; Maricopa, Phoenix; Portland, Oregon; Fort Collins, Colorado, and Albuquerque, New Mexico, and the general range of hosts of J. lecontei was established. Additional information came from Dr. T. S. Thatcher, Colorado State University; Dr. E. L. Ward, Brigham Young University, and Dr. W. E. Anderson, Insect Identification and Parasite Introduction Research Branch, Beltsville, Maryland.

Learning Injured Trees

The field study was begun in early May, 1958, by surveying areas newly infested by J. lecontei. Newly infested trees were located by surveying the ponderosa pine forest for pines with falling foliage or reddish boring dust on the bark (Figure 4). Boring dust consists of strands of phloem (with some xylem) plus cambium pushed out of the entrance holes as the beetles construct their galleries. The dust lodges below bark scales, entrance holes, and in spider webs on the tree. Dust was often difficult to see, especially when the beetles had infested the top of a tree, but by keeping trees between the surveyor and the sun, and striking them sharply with a hard stick, clouds of boring dust were dislodged and easily seen from the ground. This system worked well even in locating top-infested trees up to 18 inches DBH¹.

1. DBH is a forester's term for the diameter of a tree at breast height or 4 1/2 feet from the ground.



Figure 8. Appearance of the *Ammonia* mineral
out on the plate. (Litho. number 1).

When J. *longipalpis* has successfully infested a tree, the following "Index" through several years will be determined. Index were taken on the degree of feeding of the groups of infested trees studied on the 1961 level progressed. Thus, the state of development of the 1961 brood within in the tree could be determined by aerial or ground surveys.

Index of progression and flight periods

When an infested group of trees was located, they were marked with a hand saw and numbered on the exposed wood with a red pencil. The pencil marks remained visible for over one year. A sample of bark was removed from the infested area and examined to be sure that the tree was newly infested by J. *longipalpis*. Another series of bark samples were taken to determine the lowest point of the infested bark area and the bottom of a wire screen cage was affixed to this point (Tables 1, 2, and 3).

The cages used were similar to those used by Roney (1961) during his studies of the southwestern pine beetle. To construct the cages, a ring from a golf ball jar was soldered to the bottom of a section of 14-inch galvanized wire screen approximately 4 feet high and 4 feet wide.

A 4-inch strip of bark was removed from the infested trees around the edges of the cages so that the cages could be nailed or stapled directly to bark wood and thus prevent the beetles from escaping by burrowing out from under the edges. The size of the cages was modified with the sites in the field, depending on the size of the infested area. Some of the infested portions of the trees were high off the ground, necessitating the use of an extension ladder or climbing trees in order to affix the cages. For example, the lowest point of the highest cage was 22.1 feet from the ground (Figure 1).

Table 14. Description of cages and post-race plans collected by JIM JACOBSON, University of Arizona, Tucson, Arizona.

Experiment 1
August 1974, 140-15

Estimated base height				
Cage no.	Time Bd. L. (seconds)	Dist. off time at top of cage (feet)	Dist. off time at bottom of cage (feet)	Dist. off bottom of cage (feet, ground (feet))
1	20	10	10	11.0
2	20	0	0	11.0
3	21	0	20	10.0
4	0	0	0	9.0
5	0	0	0	11.0
6	0	0	0	9.0
7	0	0	0	9.0
8	0	0	0	9.0
9	0	0	0	9.0
10	0	0	10	11.0
Total	20			104.0
Average	6.4	1.0	8.00	10.4

Table B.—Development of roots and position plans indicated by Jim Langford, Jr., Forester, Wisconsin (June-August, 1910)

Experiment 22
(started July 14-15, 1909)

Reference Mark Dug					
Days (1910)	Tree D.B.H. (center)	Dist. at base at top of roots (feet)	Dist. of tree at bottom of roots (feet)	Dist. dist. of base of roots	Dist. of bottom of roots from ground (feet)
10	7	7	0	8.0	8.0
11	7	8	0	8.5	7.5
14	8	8	0	7.5	7.5
17	8	8	0	7.5	7.5
20	8	8	0	8.0	8.0
23	8	8	0	8.0	8.0
26	8	8	0	8.0	8.0
29	8	8	0	8.0	8.0
32	8	8	0	8.0	8.0
35	8	8	0	8.0	8.0
38	8	8	0	8.0	8.0
41	8	8	0	8.0	8.0
44	8	8	0	8.0	8.0
47	8	8	0	8.0	8.0
50	8	8	0	8.0	8.0
53	8	8	0	8.0	8.0
56	8	8	0	8.0	8.0
59	8	8	0	8.0	8.0
62	8	8	0	8.0	8.0
65	8	8	0	8.0	8.0
68	8	8	0	8.0	8.0
71	8	8	0	8.0	8.0
74	8	8	0	8.0	8.0
77	8	8	0	8.0	8.0
80	8	8	0	8.0	8.0
83	8	8	0	8.0	8.0
86	8	8	0	8.0	8.0
89	8	8	0	8.0	8.0
92	8	8	0	8.0	8.0
95	8	8	0	8.0	8.0
98	8	8	0	8.0	8.0
101	8	8	0	8.0	8.0
104	8	8	0	8.0	8.0
107	8	8	0	8.0	8.0
110	8	8	0	8.0	8.0
113	8	8	0	8.0	8.0
116	8	8	0	8.0	8.0
119	8	8	0	8.0	8.0
122	8	8	0	8.0	8.0
125	8	8	0	8.0	8.0
128	8	8	0	8.0	8.0
131	8	8	0	8.0	8.0
134	8	8	0	8.0	8.0
137	8	8	0	8.0	8.0
140	8	8	0	8.0	8.0
143	8	8	0	8.0	8.0
146	8	8	0	8.0	8.0
149	8	8	0	8.0	8.0
152	8	8	0	8.0	8.0
155	8	8	0	8.0	8.0
158	8	8	0	8.0	8.0
161	8	8	0	8.0	8.0
164	8	8	0	8.0	8.0
167	8	8	0	8.0	8.0
170	8	8	0	8.0	8.0
173	8	8	0	8.0	8.0
176	8	8	0	8.0	8.0
179	8	8	0	8.0	8.0
182	8	8	0	8.0	8.0
185	8	8	0	8.0	8.0
188	8	8	0	8.0	8.0
191	8	8	0	8.0	8.0
194	8	8	0	8.0	8.0
197	8	8	0	8.0	8.0
200	8	8	0	8.0	8.0
203	8	8	0	8.0	8.0
206	8	8	0	8.0	8.0
209	8	8	0	8.0	8.0
212	8	8	0	8.0	8.0
215	8	8	0	8.0	8.0
218	8	8	0	8.0	8.0
221	8	8	0	8.0	8.0
224	8	8	0	8.0	8.0
227	8	8	0	8.0	8.0
230	8	8	0	8.0	8.0
233	8	8	0	8.0	8.0
236	8	8	0	8.0	8.0
239	8	8	0	8.0	8.0
242	8	8	0	8.0	8.0
245	8	8	0	8.0	8.0
248	8	8	0	8.0	8.0
251	8	8	0	8.0	8.0
254	8	8	0	8.0	8.0
257	8	8	0	8.0	8.0
260	8	8	0	8.0	8.0
263	8	8	0	8.0	8.0
266	8	8	0	8.0	8.0
269	8	8	0	8.0	8.0
272	8	8	0	8.0	8.0
275	8	8	0	8.0	8.0
278	8	8	0	8.0	8.0
281	8	8	0	8.0	8.0
284	8	8	0	8.0	8.0
287	8	8	0	8.0	8.0
290	8	8	0	8.0	8.0
293	8	8	0	8.0	8.0
296	8	8	0	8.0	8.0
299	8	8	0	8.0	8.0
302	8	8	0	8.0	8.0
305	8	8	0	8.0	8.0
308	8	8	0	8.0	8.0
311	8	8	0	8.0	8.0
314	8	8	0	8.0	8.0
317	8	8	0	8.0	8.0
320	8	8	0	8.0	8.0
323	8	8	0	8.0	8.0
326	8	8	0	8.0	8.0
329	8	8	0	8.0	8.0
332	8	8	0	8.0	8.0
335	8	8	0	8.0	8.0
338	8	8	0	8.0	8.0
341	8	8	0	8.0	8.0
344	8	8	0	8.0	8.0
347	8	8	0	8.0	8.0
350	8	8	0	8.0	8.0
353	8	8	0	8.0	8.0
356	8	8	0	8.0	8.0
359	8	8	0	8.0	8.0
362	8	8	0	8.0	8.0
365	8	8	0	8.0	8.0
368	8	8	0	8.0	8.0
371	8	8	0	8.0	8.0
374	8	8	0	8.0	8.0
377	8	8	0	8.0	8.0
380	8	8	0	8.0	8.0
383	8	8	0	8.0	8.0
386	8	8	0	8.0	8.0
389	8	8	0	8.0	8.0
392	8	8	0	8.0	8.0
395	8	8	0	8.0	8.0
398	8	8	0	8.0	8.0
401	8	8	0	8.0	8.0
404	8	8	0	8.0	8.0
407	8	8	0	8.0	8.0
410	8	8	0	8.0	8.0
413	8	8	0	8.0	8.0
416	8	8	0	8.0	8.0
419	8	8	0	8.0	8.0
422	8	8	0	8.0	8.0
425	8	8	0	8.0	8.0
428	8	8	0	8.0	8.0
431	8	8	0	8.0	8.0
434	8	8	0	8.0	8.0
437	8	8	0	8.0	8.0
440	8	8	0	8.0	8.0
443	8	8	0	8.0	8.0
446	8	8	0	8.0	8.0
449	8	8	0	8.0	8.0
452	8	8	0	8.0	8.0
455	8	8	0	8.0	8.0
458	8	8	0	8.0	8.0
461	8	8	0	8.0	8.0
464	8	8	0	8.0	8.0
467	8	8	0	8.0	8.0
470	8	8	0	8.0	8.0
473	8	8	0	8.0	8.0
476	8	8	0	8.0	8.0
479	8	8	0	8.0	8.0
482	8	8	0	8.0	8.0
485	8	8	0	8.0	8.0
488	8	8	0	8.0	8.0
491	8	8	0	8.0	8.0
494	8	8	0	8.0	8.0
497	8	8	0	8.0	8.0
500	8	8	0	8.0	8.0
503	8	8	0	8.0	8.0
506	8	8	0	8.0	8.0
509	8	8	0	8.0	8.0
512	8	8	0	8.0	8.0
515	8	8	0	8.0	8.0
518	8	8	0	8.0	8.0
521	8	8	0	8.0	8.0
524	8	8	0	8.0	8.0
527	8	8	0	8.0	8.0
530	8	8	0	8.0	8.0
533	8	8	0	8.0	8.0
536	8	8	0	8.0	8.0
539	8	8	0	8.0	8.0
542	8	8	0	8.0	8.0
545	8	8	0	8.0	8.0
548	8	8	0	8.0	8.0
551	8	8	0	8.0	8.0
554	8	8	0	8.0	8.0
557	8	8	0	8.0	8.0
560	8	8	0	8.0	8.0
563	8	8	0	8.0	8.0
566	8	8	0	8.0	8.0
569	8	8	0	8.0	8.0
572	8	8	0	8.0	8.0
575	8	8	0	8.0	8.0
578	8	8	0	8.0	8.0
581	8	8	0	8.0	8.0
584	8	8	0	8.0	8.0
587	8	8	0	8.0	8.0
590	8	8	0	8.0	8.0
593	8	8	0	8.0	8.0
596	8	8	0	8.0	8.0
599	8	8	0	8.0	8.0
602	8	8	0	8.0	8.0
605	8	8	0	8.0	8.0
608	8	8	0	8.0	8.0
611	8	8	0	8.0	8.0
614	8	8	0	8.0	8.0
617	8	8	0	8.0	8.0
620	8	8	0	8.0	8.0
623	8	8	0	8.0	8.0
626	8	8	0	8.0	8.0
629	8	8	0	8.0	8.0
632	8	8	0	8.0	8.0
635	8	8	0	8.0	8.0
638	8	8	0	8.0	8.0
641	8	8	0	8.0	8.0
644	8	8	0	8.0	8.0
647	8	8	0	8.0	8.0
650	8	8	0	8.0	8.0
653	8	8	0	8.0	8.0
656	8	8	0	8.0	8.0
659	8	8	0	8.0	8.0
662	8	8	0	8.0	8.0
665	8	8	0	8.0	8.0
668	8	8	0	8.0	8.0
671	8	8	0	8.0	8.0
674	8	8	0	8.0	8.0
677	8	8	0	8.0	8.0
680	8	8	0	8.0	8.0
683	8	8	0	8.0	8.0
686	8	8	0	8.0	8.0
689	8	8	0	8.0	8.0
692	8	8	0	8.0	8.0
695	8	8	0	8.0	8.0
698	8	8	0	8.0	8.0
701	8	8	0	8.0	8.0
704	8	8	0	8.0	8.0
707	8	8	0	8.0	8.0
710	8	8	0	8.0	8.0
713	8	8	0	8.0	8.0
716	8	8	0	8.0	8.0
719	8	8	0	8.0	8.0
722	8	8	0	8.0	8.0
725	8	8	0	8.0	8.0
728	8	8	0	8.0	8.0
731	8	8	0	8.0	8.0
734	8	8	0	8.0	8.0
737	8	8	0	8.0	8.0
740	8	8	0	8.0	8.0
743	8	8	0	8.0	8.0
746	8	8	0	8.0	8.0
749	8	8	0	8.0	8.0
752	8	8	0	8.0	8.0
755	8	8	0	8.0	8.0
758	8	8	0	8.0	8.0
761	8	8	0	8.0	8.0
764	8	8	0	8.0	8.0
767	8	8	0	8.0	8.0
770	8	8	0	8.0	8.0
773	8	8	0	8.0	8.0
776	8	8	0	8.0	8.0



Figure 2. Cops placed high in ponderosa pine
at lower limit of *Pin. jeffreyi* infestation.

After the eggs were removed to a corner of the infested tree, plot trees per were attached to the eggs. Thus, infested bark, varying in area from 4.1 to 11.6 square feet, was enclosed in a wire cage with a "funnel" at the bottom emptying into the Mason jar (Figures 1 and 2). Before these insects were needed for study, the Mason jars were filled with water to prevent the emerging insects and their predators from leaving such other as possible.

At weekly intervals the Mason jars were removed, the material placed into a Uniphore fish dip net, and the insects collected were placed in numbered vials of alcohol. The fine mesh of the dip net permitted the capture of minute insects that would otherwise pass through 1/8-inch screens. The specimens of J. longicollis that emerged were counted and sorted into two categories: 1) emerging parent adults, and 2) colony adults (the progeny of the parent adults). The colony adults were at least partly yellowish-brown, while the parent adults were entirely blackish-brown. When the colony adult emergence passed its peak, newly infested trees were located and the above procedure repeated. Thus, the number of generations was determined from the time the last insect left the pine forest until the following spring.

In addition, all associated insects were collected, counted, sexed, and sent to Washington for identification. Observations were also made on associated insects in order to determine if they were predators or parasites on J. longicollis.

During the first year of the study every tree in a 4-acre plot was examined weekly to determine the major J. longicollis flight periods. For J. longicollis observations proved to be widespread and spotty, as the plot was abandoned. Instead, a general surveying of the Prescott National



FIGURE 44. *Bombus* pupae on group of postboreal pine saplings infested with *B. terrestris*.

Forest was done weekly beginning in April in American oaks (see Figure 1) and during the same period in the European oaks (see Figure 2).

Wink traps as described by Chapman and Daugherty (1958) were used and set in the American flight periods. Five 34-by 34-inch pieces of glass were set in wooden frames and hung over a trough containing water. The troughs were changed at 8:00 AM, 12:00 P., and 5:00 PM daily when hoppers began to emerge into the summer cages. At other times the 1-gal. troughs in the troughs were changed every evening. The window traps were placed in position on June 22 and removed on August 4.

An ultraviolet and a white-light trap were placed in the pine forest to see if L. laevis could be attracted and removed. Flight patterns determined. To be sure that there were L. laevis in the vicinity, 25 8-foot legs were set and scattered around the traps. Each trap had two 40-watt fluorescent bulbs suspended over a bottle of about 100 ml. of water. A funnel was suspended over a funnel, emptying into a funnel of alcohol. Collections were made daily for 20 weeks.

Life span

The life span in the field was determined by sampling infested trees and logs that were attacked at the same time as the sugar trees (Figure 1). By removing rings of bark from these trees at three-to five-day intervals, the stage of development of the hoppers within the sugar trees could be estimated. The population development in these infested trees served as a check on the effects of the wire cages on the length of the cycle.



Figure 7. Log used used to check progress of log tunneling. Note progress of galleries in the rock sections exposed at different times.

Regeneration of beetle-attacked

In weekly intervals we now spent an entire day surveying forests for juv infested pines. Now, infested trees were discovered their fall was assessed, they were counted if in groups, and notes taken on the possible reasons for juv attacks. In addition, at the suggestion of Dr. L. E. Stribich, glass growing close to lightning-struck trees were examined in order to determine if the grounded lightning discharges interceding over systems enough to allow successful attacks by juv (juv). A total of 11 lightning-struck trees together with their surrounding trees were found and examined.

Dr. E. A. Stribich suggested that the differences in vigor of infested versus nearby green pines should be determined by measuring the terminal shoot from the last whorl of branches to the tip. The terminal growth was compared on 100 infested and 100 non-infested sapling pines.

In order to determine if juv (juv) exhibits a decreased or height preference on host trees, the lowest point of infestation was compared to the top of the tree.

The characteristics of girdled and tapped standing trees

In order to establish the causal generation near the host trees of the first generation, first pines with a 10-inch DBH were felled leaving 4-foot stumps. The trees were cut when the new adults of Generation I¹ were just beginning their flight. To be sure that there were at least

1. The term Generation I refers to the progeny of the beetles that colonized Generation II refers to the progeny of both the Generation I beetles and the progeny of adults that had colonized and emerged to infest trees along with Generation I. Generation III consists of the progeny of both Generation II and the second brood of Generation I. Generation III individuals.



Figure 3. Snow layer on the forest floor, 1998, 100% snow-covered area (Larix laricina) (Larix laricina)

removed daily for 100 to 120 days, then weekly. A log was considered attacked as the first sign of boring was:

In order to determine if the attacking beetles had succeeded in constructing their galleries, four 4-inch square bark samples (2 square feet) were cut from the top, each side, and the bottom surface of each log 34 days after the first boring start was noted (Figure 14). A special tool was constructed for obtaining the squares (Figure 15). Beetles were collected in the hollow beetle:

Back-puncturing Beetles

At the test of the three back-puncturing *Chrysobothris*, *Chrysobothris* (20) was chosen because of its proven effectiveness against other bark beetles. *Pissodes* (3, *Pissodes*-*chrysobothris*) was suggested by Dr. J. A. Koll, Koller, Forest Insect Research, United States Forest Service, because its boring point is 140 SF as compared with 120 SF for 20 and the breeding point is 20 SF as compared with 40 SF for 20. All were tested at the rate of 2 pounds active ingredient plus 8 pounds of emulsifier Triton X-101 and Triton-171 and fast oil to make 1 gallon. This mixture was added to 4 gallons of water to make 8 gallons total mix.

Standing trees infested with *Pissodes* were killed and treated with 8-foot logs. Eight logs were treated with each fungicide, 4 were left untreated as checks. Twenty days later four 4-inch squares of bark were cut from each log and living and dead larvae, predatory larvae, and wood boring larvae were counted. In addition, the bark thickness of each sample was measured.



Figure 2. Samples of bark cut from baobabs exposed
with residual *Microplitis* to determine success of *Ag*
imicola attacks. Note gathering in sample



Figure 18. A log wrapped with a porous
sieve caught up four surface to stream mouth
of the spring stream. Note sampling tools.

EGG LARVA AND PUPA

Laboratory Studies

Description of stages and galleries

The eggs of *P. leopoldi* are oval, glossy-white with no external markings or ornamentation. They measure slightly less than 1.1 mm wide and about 1.8 mm long. They are deposited in individual stakes closed by the female in the egg galleries. In the laboratory the eggs hatched in approximately four days.

The larvae are white, wormlike, with light-brown head capsules. They grow through three instars as indicated by the appearance of head capsules (Figure 11), by the observation of newly eclosed, white-headed larvae, and by the rearing of closed head capsules. The first larval instar exceeds three days. The rearing method was not adequate to determine the duration of the other two larval instars. Reid (1933) and Ballmann (1940) also found three instars in five other *Sci* spp.

When the larvae hatch they feed gregariously in groups until the puparium feeding begins in 1 to 2 or five the egg gallery. Then they enter individual tunnels.

When nearly mature, the larvae are approximately 8 mm long. At this time they construct pupal cells in the gallery and enter a prepupal stage when they straighten out and lose their characteristic S-shape.

Under laboratory conditions the larval stage lasts approximately 11 days.

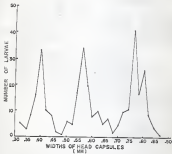


Figure 11. Widths of head capsules of *Sagittaria* larvae.

The pupae are white, approximately 1.5 mm long, becoming gradually beginning with eyes and mouthparts to a light brown as they metamorphose into adults. The pupal stage required approximately four days under laboratory conditions.

Yellow adults are light brown, becoming as they mature to black. The center of the abdomen is the last part of the body to blacken and newly emerged adults can be separated from their parents by this color difference. The yellow adults are externally identical to their parents, including secondary sex characteristics.

The adult females are 4.4 to 5.8 mm in length and have been described in detail by Jupp (1962). The largest two specimens measured, both females, were 5.2 mm longer than the 4.4 mm value listed given by Jupp.

The sex ratio of newly emerged yellow adults is approximately 1:1. In a sample of 1,261 yellow adults there were 641 males, 620 females. However, like other agg. spp., J. jansoni is sexually polygamous. A total of 48 mated specimens from 22 towns had 250 maturing egg globules, an average of 5.2 globules (females) per male.

Wood (1945) and Gaze (1946) attempted to explain the loss of males by the differences in the ability of the sexes to locate males using "pioneer" attacks. Wood found that females were attracted to larger numbers than males, while Gaze demonstrated that females respond to the male pheromone over longer distances than do males. The attacking males also expose themselves to predation for longer periods than do females.

The entire life cycle of J. jansoni at 70°F, 70 percent RH takes approximately 40 days (Table 4).

Table 1: Life cycle of the lacewing in ponderosa pine holes (approx. 700, 15 percent RH). Greatest run time 18 holes

Days following inception of holes	Stages present	Activity
0-4	Overwintering adults, eggs	Adults prepare pupal chambers Female lays egg galleries
4-6	Parasite, eggs, young larvae	Egg galleries 1.5 to 2.5 in- long. Larvae feeding pro- gressively. All eggs hatched
6-12	Parasite, eggs, larvae	First larvae about full grown
12-18	Parasite, larvae, pupae	Parasite begins to leave holes. Larvae full grown and beginning to pupate.
18-24	Two parasites, pupae, adult adults	Parasite have almost com- pletely deserted holes. Adult adults light brown
24-28	Pupae, adult adults	Adult adults increasing, feeding some pupal cells.
28-32	Two adults	Two adults active, emerging from holes.

The egg galleries of L. [spinosus] [reduncus] in a [reduncus] [reduncus] : central apical chamber connected to the phloem by the [reduncus] [reduncus] 1/2. Occasionally the chamber crosses the xylem. The galleries generally are parallel to the grain of the wood and each is constructed by an individual female so that the xylem is preserved for almost a third of the diameter of the gallery. The galleries are kept clear of boring dust by the combined efforts of the male and females.

The length of the egg galleries is variable. Under unstarved laboratory conditions 50 galleries averaged 7.3 inches. Frequently, a gallery 1 inch or less in length is constructed by the male, possibly for feeding. In the field galleries are longer; 50 galleries averaged 8.4 inches. The longest gallery measured extended 8 feet 3 inches from the apical chamber.

Egg clusters are found on either side of the gallery, often in groups of 10 to 15. When two galleries closely parallel each other, eggs are laid singly on the outer edge of each gallery.

Feeding

Under laboratory conditions 50 mated females of L. [spinosus] [reduncus] that constructed egg galleries laid from 11 to 120 eggs; average 45. No dissections were made to determine the extent of [reduncus] [reduncus] which reduces the number of eggs a female can lay.

In the field, females laid 1,450 eggs in 554 inches of gallery or 4.1 eggs per inch. Since the average egg gallery under natural conditions is about 28 inches long, the female lays approximately 45 eggs.

The egg galleries of re-emerging parents are approximately the same length although a direct comparison is difficult since the re-emerged adults were placed in freshly cut holes within wooden cages. (2' 41)



Figure 10. *Spinal and pelvic of the human*
bone found in the same place

galleries observed, there was only an average of 21 eggs laid. Only 11 beetles emerged for the second time, but they died without constructing their third gallery.

The six larval stages of scarab beetles

Test 1 - In the first test no water was supposed to be present. All 16 scarab yellow beetles placed in artificial mycelial chambers left them unattended. Eight of the 16 crawled to the lower end of the bait and were gathered averaging 1.6 inches. An attempt was made to lay eggs or construct egg tubes. The remaining 8 beetles died outside the bait. Dissection after two weeks showed eggs to be present in all 16 beetles.

The beetles collected as emerging yellow were similarly. Only six of 16 beetles constructed galleries and two of those above the surface of the bait and at the upper end of the bait to begin galleries were though the water was used. Galleries were short, averaging 1.8 inches. No eggs were laid.

In order to study provided a hole to be introduced in a hole containing three beetles. The hole constructed a new mycelial chamber where a link had been removed from the bait. The three beetles joined him and constructed normal egg galleries. At the end of two weeks they were still laying eggs and had produced 73 partially grown larvae.

Test 2 - When the beetles were confined to the artificial mycelial chamber by placing them in 16 in small vials fastened to the mycelial chamber with modeling clay, all but three constructed short chambers, but none laid eggs. Of the five pairs of beetles placed with water three individuals died, but the rest made normal galleries and laid eggs.

Test 2 - The mounted females had to be discarded from this test because no males were found at the time in which they were working. The usually emerged male females again made short galleries, but laid no eggs. This time some of the 30 beetles died in the vials, probably because they could not come out the hole from the slippery glass surface.

These tests indicated that newly emerged females do not mate before the dispersal flight. Mating is apparently required for egg deposition, although eggs are formed in virginity. The postaggregation of a male might stimulate mounted females to deposit eggs, but this was not tested.

Field Studies

Geographical distribution

Almost all locality records of *I. lecontei* have come from ponderosa pine in Arizona. Within the boundaries of Mexican and Central American pine have been poorly collected as *I. lecontei* is not an important pest south of the United States.

At no time during this study was the closely related *I. confusus* collected from ponderosa pine although ponderosa pine is its primary host in California. Instead, *I. confusus* confines its attacks to pines in Arizona and New Mexico.

In the northern and western limits of the range of *I. lecontei*, *I. adii* becomes the principal pest of ponderosa pine. Unusually, *I. adii* was never taken from pines infested by *I. lecontei*, although it was common in spring ponderosa pines in New Mexico.

Figure 22 shows the geographical distribution of *I. lecontei* compiled from many sources, but particularly from Hopping (1958). The distribution of host trees is from Strickfield and Little (1960).



Figure 13. Geographical distribution of *Laguncularia racemosa* and other species.

Flight periods and nature of parasitism

The first generation of *A. laetatorius* begins when the beetles leave the trees in which they have been overwintering and defoliate slash, wind-thrown trees, or standing trees severely weakened or dead. The overwintering beetles never attacked and killed green standing pines in their first spring flight during the three years of this study. Apparently, the height of pine in the spring is rarely low enough to permit successful attacks. The flight attacks were made between April 18 and 26 during the first two years at Fort Huachuca, Arizona. In one case a group of pole-sized pines (average ± 4 inches DBH) was infested by *A. laetatorius*. The pines had been severely defoliated the year before by *Diprionidius* sp. eating the tops. In addition, wounded larvae were actively eating in the wood, indicating that the pines had been weakened or dead for at least a year.

The trees of the infested group were caged on May 15, the cages covering 104.3 square feet of bark (Table 1). By June 1-15, most of the pines had emerged. Their progeny, Generation I, were in late larval and pupal stages. The pines attacked apparently healthy trees and began a second burst. The new adults of Generation I reached a peak of emergence on July 3 and by July 17 had almost completely deserted the trees. The progeny are strongly attracted to trees only infested by their parents and habitually fill the infested bark area in their parents' host trees or in nearby trees.

From July 24 to 27, a total of 44.8 square feet of bark was caged on 13 infested trees (Table 1). There were two peaks of emergence of new adult adults (Generation II) from these trees; one on August 13, and a second on August 26. These peaks corresponded to the emergence of

the progress of the re-attacking psyllids that had colonized the new progress of Generation I. Again there was a re-interphase of parent adults and again these new psyllids became the focal point of new infestations.

By August 18, the foliage of the plant infested July 4 was beginning to "fade." First the foliage turned to a pale green, then to a yellowish-green (Figure 14), and finally to a "burned" or withered brown. While the numbers of emerging yellow adults peaked a few days after fading was noticeable, fading foliage does not usually make a good indicator for ground crews spraying uninfested trees for chemical control. However, the emerging beetles frequently attack withered bark on the same trees in which they developed, as it is possible for L. agilis to be present in faded tissue.

For two years the status of August was the earliest date falling foliage began to show up in the Phoenix National Forest. Serial surveys should not be made any earlier.

In August 17, 18 additional newly infested trees were noted covering 144.4 square feet of bark area (Table 2). Most of the trees emerged from October to November 3, well after the advent of cold weather made new attacks impossible. The psyllids continued to leave these trees on more days to November 3.

Over 4 square feet of infested bark area outside the cages was examined in January. Only 18 beetles were found overwintering. For two years, trees containing beetles in December had few or none by the end of the winter. However (1968), however, found populations as high as 124 L. agilis per square foot overwintering in the holes of infested ponderosa pine in which they had developed. None of these beetles



FIGURE 14. *Scotsman pine* infected by *Juniper*. Attached July 41. Photo taken August 28.

probably augmented from other host trees since the highest density recorded during the summer generations was slightly over 16 beetles per square foot.

1st generation: therefore, goes through three complete generations each year in the Forestry, Arkansas area. The life cycle data obtained from the cages and from examining infested trees outside the cages are summarized in Tables 4 and 5.

Shade traps, set up to determine seasonal and diurnal flight periods, did not prove practical. The few 1. laevigata were trapped to make any but the most casual observations on flight patterns. In general, this species was rarely collected until early afternoon. Night temperatures would drop to 70F or below although by noon air temperatures would rise to 70F or higher. When examining cut logs for new attacks during the overwintering trials, few 1. laevigata attacks were found before 2-20 PM.

2nd generation was never collected in either the shade or illuminated light trap. The 20 logs examined around the traps became infested, but either light was not attractive or night temperatures were too low to allow 2nd flight.

The overwintering of girdled and injured standing trees

None of the cut stumps or girdled trees was successfully attacked by 1. laevigata. The largest beetles died and the 2nd flight bypassed the 4-foot stumps. After eight weeks the cut stumps were infested by 1. planipennis and Hesperus subseriatus (Dowr.). The foliage of the girdled trees did not fade until the following season. They were all eventually attacked by the overwintered, Hesperus sp., none was ever infested by 1. laevigata.

Table 1. Summary of nitrogen input data [see Journal, Fremont National Forest, Arizona]

Observation	Estimated N input Cg/yr	N ₂ present atmos	N ₂ input	Total N ₂	N ₂ Deficit Cg/yr	Percent of N ₂ input
I	104	207	107	410	4.3	1.1%
II	59	114	6,448	6,571	45.5	1.3%
III	309	2,162	6,744	6,945	46.9	1.1%

Table 4. *U. glauca* pupal life and food development. Length of cycle of 1st [second]. Emergence, 1958-60.

Instar (1st)	Pupal emergence	Peak emergence	Approx. time taken for development (in days)			Approximate total cycle (in days)
			Egg	Larva	Pupa	
I	April 21	July 1	4	16	1	21
II	July 1	August 13	4	12	1	17
III	August 21	Nov. 1	4	20	10	34

I—Gallium adults often remain under bark for long periods after emerging from the pupal stage.

have a close agree with the findings of Vitz and Redinsky (1988) that the abscissa (vertical position of logged standing ponderosa pine canopies, that clearly decreases over several weeks. They also found that attacks are uncorrelated for trees in seven weeks following cutting. The s.e.p. of girdled trees remains normal until the time died. They found girdling to have no effect on bark beetle infestations.

Characteristics of logs attacked

The beetles most often infested living trees with diameters of 1 to 12 inches at the point of attack (Figure 11). For trees and logs with larger diameters are often infested. The smallest diameter in which a successful gallery was found was a 1/8-inch diameter branch from the top of a ponderosa pine, several half-grown larvae were in galleries extending from an egg gallery.

Twisted limbs are popular to ponderosa pines. Groups of up to 70 are frequently attacked and killed (Figure 12). The tops of larger distorted pines are also killed and "wing-headed" pines are a common sight within the range of J. monticola.

Lightning-struck trees rarely become a source of attraction for J. monticola, although Agathidium uliginosum (Stansford) and J. ulmum (Cn.) attacked the bases of six of eleven lightning-struck trees. However, none were killed by the beetles.

There was no difference between the ages of infested versus non-infested trees as determined by a comparison of the length of terminal shoots. The terminal shoots of 100 infested trees averaged 2.3 ± 1.1 inches, 100 uninfested shoots averaged 2.1 ± 1.1 inches.

During the investigation of the pine stand for infested trees, a large number of pines were found infested in the same time areas and

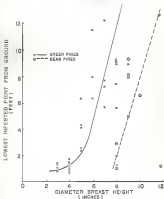


Figure 14. The relationship of tree diameter to the lowest point from the ground infested by *24g* beetles.



Figure 14. Group of 20 pines killed by *Ann
Larvella* in the Penasquito National Forest.

Myadestes "after" stops the song of Ag. ruberocinctus was an adequate water supply or a weakened nest species which amounted to the same thing. The second most frequent cause was the cutting and piling of pine logs and slash. This material became infested and the attacking Ag. set up a secondary attraction to Ag. in flight which attacked and killed straggling trees nearby. The following are examples of an inadequate water supply:

- Ex. 1. A group of 22 singing parus pine was killed by J. leucurus when told from a sapling tree excavation was piled against them.
- Ex. 2. Three pine, suitable for slash, were attacked and killed when their water was held out away during the excavation for a time.
- Ex. 3. A single 22 tree was heavily attacked when a porch was built around it, completely shutting off its water supply.

The following cases were examples of trees infested near a source of attractive material:

- Ex. 4. A road building project shows the 14, Fraxinus trail off the deeper back had left many trees pushed over or cut down. The groups of trees became infested by J. leucurus and J. leucurus in the vicinity of the dead trees. Approximately 25 trees were killed in each group.
- Ex. 5. A road line survey showed a right-of-way through some parus pine timber. A nearby group of 22 green trees was attracted by J. leucurus and a couple of Myadestes species. In this case there may have been some building in the dead trees.
- Ex. 6. A dirt road was constructed out over logs and piled them in a series in early summer. Immediately adjacent to the pile, a group of 22 green trees was attacked and killed by J. leucurus and J. leucurus.

Associated fauna

During the field phase of this study observations were made to try to determine what species of larva were influential in inducing Ag.

lanceae populations by predation, parasitism, or even interference in competing for space under the bark. With one exception, these appeared to be little influenced by natural control agents.

The exception was in the first generation when J. lanceae infested dead standing logs. The wooded area was highly populated with what appeared to be overwintering adults of Phryganea sp., a barkbeetle. These beetles were entirely predaceous on larvae and adults of J. lanceae. Their presence probably had a great influence on the small numbers of J. lanceae emerging since a total of 494 Phryganea and 494 J. lanceae were collected from the logs. Several times a Phryganea was observed capturing and eating a larva or adult of J.

larvae.

When J. lanceae was attacking, especially from July to September, three species of clerid beetles were seen feeding on them. The largest and most common was the white-bellied clerid, Eucinetus albifrons (Fab.) less common were the black-bellied clerid, J. lanceae Wbl., and J. rufipes (Mg.). In spite of what appeared to be heavy predation the J. were able to infest trees and logs in large numbers.

Barryman (1945) described the behavior of J. lanceae attacking J. longipennis. The clerid complex observed in nature at present had similar habits. J. lanceae habitually moves rapidly over the bark when attacking a tree then abruptly stops and remains motionless for several minutes before moving again. When adults of J. lanceae were among the adult clerids would frequently attack them, lifting them completely off the bark and showing out the body joints. The frequent stops by J. lanceae could be a defense reaction against clerid predation since sometimes J. were not attacked. Larvae of these clerids and

of another predator, the catbird hawk, *Amorphus astrophysalis* Schiff., were common in *J. jessiae* galleries, but frequently resulted in egg loss.

Waspophores were not common but the hairy waspophore, *Agrobatus affinis* (G.) and the drump waspophore, *Agrobatus pubescens* (Hovis.) were observed hawking on infested trees. The white-throated nuthatch, *Sitta carolinensis* Lath., was commonly observed pecking like waspophores at *Jes* infested bark.

The most common predator on *J. jessiae* larvae was the toyard wasp, *Agromyza ruficeps* (Hovis). The larvae feed on crispwood on the hosts and pupate in the larval skins.

Several species of beetles, notably scolytids, curculionids, and longhorn, competed for food with *J. jessiae* in the cambial region. *Las masticophagus* was a common associate, but only in the first generation when *J. jessiae* infested dead trees. When logs were freshly cut a longhorn with a metallic blue sheen, *Stenomacrus pallidus* Grav., would lay eggs in niches in the bark. The larvae feed in the central area, reducing the bark available for *Jes* development. Almost all other species competing as natural top log feed to influence *J. jessiae*.

The following list are those species of insects collected from trees collected with *J. jessiae*. They were identified by the staff at the United States National Museum. Others are excluded from the list. The numbers were identified by Dr. E. L. Muese.

The letters preceding the species names indicate the habits as related to J. japonica:

p - observed to be parasitic
 pf - probably parasitic, not observed
 pred - observed to be predacious
 ac - assassin
 com - collection of J. japonica for food (spare)
 no letters - relationship not known

Hymenoptera

Proctotridae

p-Enallagma habealis Wesm.
 p-Enallagma sp. ? n. sp.
Enallagma sp.
Enallagma sp.
Enallagma sp.

Trypetidae

p-Trypetes occidentalis (Wesm.)
 p-Trypetes sp. (Wesm.)

Ichneumonidae

pf-Ichneumon sp.
Ichneumon sp.
Ichneumon sp.

Phygadeuonidae

Ichneumon sp.

Brachymeridae

p-Brachymeria sp. Wesm.
 p-Brachymeria sp. (Wesm.)
Brachymeria sp. (not as parasitoid)
Brachymeria sp. Wesm.

Leucospidae

Leucospa sp. (not as parasitoid)
 pf-Leucospa sp. (Wesm.)

Encyrtidae

Encyrtus sp.

Eurytomidae

Eurytoma sp.

Pompilidae

Pompilus sp. Wesm.
Pompilus sp.
Pompilus sp. (not as parasitoid)
Pompilus sp. (not as parasitoid)
Pompilus sp. (not as parasitoid)

Calyptoides

near Calyptoides longus Gen.
Calyptoides tabernulae Gen.
Calyptoides sp.

Calyptoides

Calyptoides gracilis Gen.

Calyptoides

Calyptoides sp.

Calyptoides

Calyptoides gracilis Gen.
Calyptoides sp.

Calyptoides

near Calyptoides sp. Gen.
Calyptoides sp. Gen.
Calyptoides sp. Gen.

Calyptoides

near Calyptoides sp.

Calyptoides

Calyptoides sp.

Calyptoides

near Calyptoides sp.
Calyptoides sp.

Calyptoides

Calyptoides sp.

Calyptoides

Calyptoides

Calyptoides sp.
Calyptoides sp.

Calyptoides

Calyptoides sp.

Calyptoides

Calyptoides sp.

Calyptoides

Calyptoides sp.

Calyptoides

Calyptoides

Calyptoides sp.
Calyptoides sp.

Cyrtidae

Cyrtus pubescens Howard
Cyrtus viridis Barber

Belontiidae

Belontiella maculipennis Banks & Davis
Belontiella maculipennis (Forsk.)

Pyraliidae

Pyralis glaucochloides Walker

Neuroptera

Asilidae

Asilidius sp. (Dorsal produced on g. laevis)

Beetles associated with g. laevis

Agathidium delicatum
Agathidium sp.
Agathidium sp.
Agathidium sp.
Agathidium sp.

Beetles present in g. laevis

Agathidium delicatum
Agathidium sp.
Agathidium sp.
Agathidium sp.

CHEMICAL CONTROL

Residual sprays

All but one of the residual sprays tested appeared to keep L. lineolaris and L. glaucocephala from attacking the cut logs for longer periods than if no insecticide had been applied. The exception was the unsatisfactory Dursin, an experimental formulation, which has since been dropped by the manufacturer.

The first year the residual sprays were tested was one of heavy Ag. infestation and high pine mortality. The first treatments were made on May 15. Table 3 shows the length of time the 28 chemical treatments kept the freshly cut logs free of Ag. attacks. The 1.4 percent Dursin 20 was obviously superior to all other treatments since none of the five treated logs became infested.

The logs that became infested were examined 24 days after the first logging date was observed in order to see if the attacking Ag. survived after tunneling through the treated bark. Of the five logs treated with 1.4 percent Dursin 20 two became infested with a density of two attacks per square foot, but none of the attacking beetles survived to make egg galleries (Table 3).

The next year L. lineolaris populations were low. The experiment was repeated and a 1.4 percent BHT 50 was added since the Dursin 20 showed much superior results in the Dursin water emulsion.

Table 3 shows that three of five and four of five logs treated with 1.4 percent Dursin and 1.4 percent Lindane, respectively, never became

Table 3. Number of days (positively and 2 days) resolved from all ECG attacks following transcutaneous treatment. High intensity of adaptation

Day	ECG				ECG				ECG				Period for monitoring
	100	80	1-90	1-95-100	100	80	1-90	1-95-100	100	80	1-90	1-95-100	
1	21	8	7	+	20	7	22		11	6	9		8
2	20	9	7	+	26	20	29		15	20	22		11
3	20	21	+	+	18	16	+		11	16	19		11
4	21	15	20	+	+	+	+		+	+	+		14
5	20	18	+	+	+	+	+		+	+	+		8

+: Not followed at day end of the day.

Table 4. Index of egg collection and numbers of mating chambers in legs treated with DDT, lindane, and DDT while still green. High intensity of infestation.

No. of legs	Treatment	Mating chambers (mites per sq. cm.)	Egg collection (per sq. cm.)
5	0.002 DDT	5.2	25.1
5	0.002 DDT	4.2	24.2
4	1.000 DDT	3.0	22.7
5	1.000 DDT 48	—	—
5	0.002 lindane	4.4	19.7
5	0.002 lindane	3.4	12.5
4	1.000 lindane	3.0	8.8
5	0.002 DDT	3.4	11.2
5	1.000 DDT	4.4	10.2
5	1.000 DDT	3.4	10.8
4	Control (untreated)	3.2	17.2

Table 4. Series of days freshly cut logs sampled free of *B. atroch* following insecticide treatments. Low toxicity of imidacloprid

Log	TREAT					LITIGATION					BOL					Control
	100%					50%					25%					
	10.0	10	1.00	1.00	1.00	10.0	10	1.00	1.00	1.00	10	1.00	1.00	1.00		
1	17	30	17	30	30	30	30	30	30	30	30	30	30	30		
2	20	30	20	30	30	30	30	30	30	30	30	30	30	30		
3	30	30	30	30	30	30	30	30	30	30	30	30	30	30		
4	30	30	30	30	30	30	30	30	30	30	30	30	30	30		
5	30	30	30	30	30	30	30	30	30	30	30	30	30	30		

0 = Not infested at end of 77 days

collected by 1991 spp. However, all Indian treatments and the 1:4 percent DDT WP had the lowest 1991 mortality to date galleries under the bark (Table 10).

Early-emerging *Chrysobothris*

All bark-injecting treatments killed 75 percent or more of *J. pernix* under the bark. *Chrysobothris* also killed all 50 predatory larvae of *Phaenocarpa* spp. and *Leucospis* sp., but *Chrysobothris* did not kill any of the eight predators mentioned (Table 11).

Chrysobothris was superior to both *Stenomacrus* and *Stenomacrus*, but all caused satisfactory 1991 mortality compared to controls (Table 12).

Table 28. Yields of egg galleries and numbers of nesting chalcids in eggs treated with DDT, Lindane, and DDT plus DDT groups. Low salinity of *Aspilota* spp.

No. of eggs	Treatment	Nesting chalcids (eggs per egg, fl.)	Egg gallery (eggs per egg, fl.)
5	0 DDT DDT	3.2	20.8
4	0.001 DDT	4.2	22.2
4	1 DDT DDT	3.8	24.4
4	1 DDT DDT 10'	1.2	12.2
5	0.001 Lindane	1.2	4.2
5	0.001 Lindane	0.8	4.0
5	1.001 Lindane	1.8	7.2
4	0.001 DDT	5.2	15.2
5	1.001 DDT	20.2	19.4
5	0.001 DDT	7.2	22.0
5	1.001 DDT 10'	0.2	4.2
5	Control. (Retained)	4.0	24.0

Table 11. Results of tests with ethylene dibromide, Fumigone, and Nemagon.

	Living <u>24h</u> larv. pupated			Dead <u>24h</u> larv. pupated			Pupations dead/live		Eggs dead/live	
EDB	-	-	-	11	4	49	3	-	-	-
	-	-	-	1	20	61	2	-	-	-
	-	-	-	4	-	89	2	-	-	-
	-	-	-	-	-	18	-	-	-	-
	-	-	-	10	34	56	4	-	-	-
	-	-	-	17	11	44	6	-	-	-
	-	-	-	104	-	13	-	-	-	-
	-	-	-	11	-	2	2	-	-	-
Totals: 1 no live <u>24h</u> Dead: 111 larvae, 76 pupae, 154 adults										
Mortality: 100%										
NEMAGON	3	1	-	36	33	45	-	-	-	-
	-	-	-	55	-	19	-	-	-	-
	4	-	1	30	3	1	-	1	-	-
	3	-	-	14	1	95	-	1	-	-
	-	-	-	11	-	28	-	1	-	-
	1	-	-	8	-	14	-	-	-	-
	8	-	-	66	-	11	-	8	1	-
	2	-	3	11	2	17	-	2	-	-
Totals: Live: 11 larvae, 1 pupa, 8 adults. Dead: 171 larvae, 19 pupae, 107 adults. Mortality: 98.1%										
FUMIGONE	1	-	-	7	24	19	3	-	-	-
	2	-	-	64	-	44	2	-	-	-
	1	-	-	27	17	14	4	1	-	-
	17	-	-	114	-	64	8	2	-	-
	24	-	3	34	2	44	3	2	-	-
	-	-	4	5	18	42	8	2	1	-
	2	-	-	3	11	14	3	1	-	1
	1	-	-	29	1	29	2	-	-	-
Totals: Live: 48 larvae, 3 pupae, 4 adults. Dead: 191 larvae, 11 pupae, 109 adults. Mortality: 99.2%										
EDB	7	13	19	1	1	2	-	9	4	-
	1	4	17	1	4	1	-	11	-	-
	-	-	11	-	-	1	-	7	-	-
	64	-	11	-	-	-	-	4	-	-
	1	-	71	-	1	-	-	11	3	-
	-	2	41	1	8	-	-	3	-	-
	-	-	43	1	4	4	1	19	2	-
	4	2	31	1	-	-	-	9	1	-
Totals: Live: 88 larvae, 20 pupae, 84 adults. Dead: 4 larvae, 12 pupae, 7 adults. Overall mortality: 3.3%										

1 Totals include only 24h spp.

Table 11. Analysis of backspinning (continued) by chi-square

	A DIN	B DIN	C DIN	D CONTACT	TOTAL
Good	0	10	54	97	161
Bad	666	407	645	20	1,738
Total	666	417	699	117	1,900
Total proper Good	1-0000	.9570	.9223	.8713	.9348

Comparison	df	χ^2	p <
A vs B	1	1217.96	.000
A vs C	1	189.59	.000
B vs C	1	3.66	.06 < p < .10

FOODS AND COLLECTING

Within its range in the United States, the Arizona *Leucospis* (*Leucospis leucospis*) Swain, is associated with almost all the ponderosa pine mortality caused by bark beetles. *Leucospis* is found in Arizona and western New Mexico and ranges south to Honduras, attacking five species of pines.

Feeding-damage to pines are performed and attacks on standing trees with a 12-inch diameter or larger are rare. Single trees, and tops of large trees are killed, but soon heavily groups up to 70 are attacked. Infested trees are characterized by falling foliage and boring dust on the bark.

In mid-or late-April, when the adults emerge from the trees in which they have overwintered, they confine their attacks to dead, logging debris, windblown trees, or freshly killed standing trees. The almost total elimination of pines in the spring probably prohibits *Leucospis* infestation. By the middle of May the galleries are well advanced, eggs and young larvae are present. Development is rather slow because of cool weather. Around June 1, the larvae are almost mature. The parents leave their galleries and fly to attack new trees (about 400 feet above ground, apparently heavily used). By June 15, parent emergence is complete. Their head is yellowish, pupal and mature larval stages. By the end of June, emergence of the brood begins. It has reached a "peak" by July 8 and is past the peak by July 14.

In two observed cases the brood was definitely attracted to trees adjacent to those infested by their parents. The host preference of the emerging parents may be an important factor in the epidemiology of A. bipunctatus. Thus the fourth generation in almost every group of infested trees found during the summer has indications of being infested by two or three separate "cliques."

After the first summer generation there are no definite flight periods. Trees may be infested at any time by re-emerging parent adults or their progeny.

Four seasons established two more complete cycles, one ending the middle of August, the third and last in October and November when the last brood overwinters under the bark.

The second generation requires approximately 38 days to develop from the egg to a mature adult, the same time as recorded elsewhere in the laboratory. The time of development in the field of the first and third generations is extended to 70 and 85 days because of cool spring and fall weather.

The male A. bipunctatus bores vertical flutes, constructing a spiral chamber in the lower bark. An average of 4-5 females follow and excavate egg galleries radiating from the spiral chamber. The female lays an average of approximately 25 eggs although some specimens lay over 100. Mated females do not lay eggs.

Within parts, such as those found around laminates and comp. granules, may be protected with a residual spray of 1 percent DDT ME, 0.5 to 1.0 percent lindane ME, or a 1 percent DDT ME. Eggs under the bark of infested trees may be killed with emulsions of carbaryl, chlorobenzene, diazinon, or fenitrothion at the rate of 2 lbs. active per 5 gallons of oil.

The Forest Dept. in the case of L. longirostris, the timber forest management system is the reliance of the emerging overstorying adults on cut logs or dead trees. If logging debris or cut trees are allowed to remain on the forest floor until they then treated mechanically or burned, a large part of the Lug population would be destroyed.

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EDUCATION

Edward Ottaviano was born in 1914 in Brooklyn, New York. He attended grammar school in New York City and graduated from James High School in 1932.

He attended the New York State College of Forestry at Syracuse University from 1932 to 1936. In 1934 he received a BS in Civil Engineering and in 1935 an MS in Forest Entomology.

In 1936 he married the former Elizabeth Weston of Milton, Long Island. They have three children.

From 1936 to 1940 he was employed as a forest entomologist with the U. S. Forest Service, Rocky Mountain Forest and Range Experimental Station at Fort Collins, Colorado, and Albuquerque, New Mexico.

In 1940 he attended the University of Florida where he was granted a working-research assistantship. In 1942 he accepted a position as entomologist with the United Fruit Company in La Lima, Ecuador, where he is currently employed.

He is a member of the Entomological Society of America, Florida Entomological Society, Sigma Xi, Xi Sigma Phi, Forestry Society, and Sigma Sigma Delta, Agricultural Society.

This dissertation proposed research in contemporary philosophy of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Board of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August 13, 1960

Samuel H. Smith
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